Comparison of Setting Time, Setting Expansion and Compressive Strength of Gypsum Casts Produced by Mixing of Gypsum Powder with Distilled Water or 0.05% Sodium Hypochlorite

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Abstract

Objective: Previous studies have demonstrated that dental stone casts can be disinfected by replacing 10% of required water with 5.25% sodium hypochlorite solution. This comparative study evaluated physical properties of dental stone models produced by replacing distilled water with sodium hypochlorite.

Methods: In this in-vitro experimental study, a total of 45 dental stone models were produced in the following 3 groups. Group A included stone models fabricated by mixing 300g gypsum powder and 94 mm³ distilled water. Group B comprised of stone models produced by mixing 300 g gypsum powder and 94 mm³ diluted 0.5% sodium hypochlorite solution. The third group (C) included specimens produced by mixing 300 g gypsum powder and 90 mm³ distilled water. Setting time, setting expansion and compressive strength of specimens were measured and compared. All tests were carried out according to ADA Specification No.25. Obtained results were entered SPSS software. ANOVA was applied for the comparison of 3 groups and Tukey’s test was used for pair wise comparison.

Results: Replacing distilled water with sodium hypochlorite caused a statistically significant reduction in setting time (mean reduction of 515 s) and increased the compressive strength of samples (mean increase of 4.06 MPa). Setting time in group 2 specimens was shorter than that in group 3 samples but no statistically significant difference was noted in setting expansion of samples in the 3 groups.

Conclusion: Replacement of distilled water with sodium hypochlorite had no adverse effect on setting time, setting expansion or compressive strength of dental stone casts and thus can be used as a suitable method for disinfection of casts in dental laboratories.

Key words: Compressive strength, Dental stone, Disinfection, Setting expansion, Setting time, Sodium hypochlorite.

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Introduction:

Among different materials, gypsum is the most commonly used substance to make a duplicate of the teeth. Dental stone casts are the connection between the clinical and the laboratory phases of treatment and reconstruct the desired structures (1). In prosthodontic treatments, impressions are made of teeth using dental impression materials. Thus, these materials are in direct contact with the oral mucosa, saliva and blood and can act as a carrier for potential transmission of microorganisms to dental personnel. Contaminated impression materials and prostheses are the most important route of infection transmission from patients to the lab environment (2). Impressions are usually contaminated with blood and saliva and simple
rinsing is not sufficient for their decontamination (3). These contaminants can also be transferred to dental casts and the cycle of infection transmission and cross contamination continues as such (4). To confront this phenomenon, more emphasis has been placed on irrigation and disinfection of impressions before sending them to the lab (5-7). Some researchers have investigated the effect of disinfection on dimensional stability of impressions (8-10). Some others have evaluated the efficacy of disinfection in reducing the level of microbial contamination (11, 12). Spraying the impressions with disinfectants has also been reported as an effective technique for reducing contamination without adversely affecting the dimensional stability of stone model (13, 14). Immersion of impressions into the disinfection solution has also been suggested as a suitable method to decrease microorganisms (15). Rinsing the impression with water may reduce the contamination to a great extent but some levels of contamination may still exist. Obviously, while doing dental procedures, dentists are at risk of contracting a wide range of diseases from a common cold to TB, hepatitis and AIDS (11, 12). On the other hand, it has been demonstrated that immersion of dental casts into the sodium hypochlorite solution has no significant adverse effect on stone cast quality (16-19).

Ivanovski et al. (1995) evaluated the effect of incorporating disinfecting solutions into gypsum on level of contamination and physical properties of the casts and supported the concept of incorporation of disinfecting agents into stone models as a standard operating procedure (20). Furthermore, 0.525% sodium hypochlorite and 0.1% povidone iodine have been proposed as disinfectants with no adverse effect on dimensional stability of dental stone casts (21).

In a study conducted in 2003, gypsum was mixed with water containing 0.5% calcium hypochlorite resulting in a reduction in number of microorganisms and improvement of mechanical properties of the casts (22). Adequate compressive strength is among the most important characteristics of dental stone casts enabling them to adequately resist against applied forces during prosthetic laboratory procedures. Setting time and setting expansion are also important. It should be noted that when gypsum is mixed with water, only 18.61g of water chemically reacts with 100g of gypsum and the remaining water is left unreacted. In fact, the excess water is for better wetting of gypsum powder and formation of a thinner mixture for easier impression pouring. However, it weakens the final quality of the set stone (23). This study sought to assess the compressive strength of dental stone casts produced by mixing gypsum powder and 0.5% sodium hypochlorite and compare it with compressive strength of casts made of mixing gypsum powder and distilled water. Setting time and setting expansion were evaluated as well. The third group was also included to assess the effect of reducing the amount of water on the mentioned properties and to make a comparison with specimens made by incorporation of less water and hypochlorite. Thus, this study aimed to compare the effect of addition of hypochlorite on physical properties of the conventional casts (with distilled water) and those produced with less volume of water.

Methods:

In this in-vitro experimental study, a total of 45 dental stone (Type III dental stone, Pars Dandan, Tehran) casts were produced in 3 groups of 15. By considering the significance level of alpha=0.05, study power of over 80%, equal number of specimens in the 3 groups, standard deviation of 30s for the setting time in the pilot study, specification of 60s setting time, 15 to 20% loss to follow up and 5-7 samples in each group, sample size was calculated as 21. However, 45 specimens were evaluated in our
study. In group A, 300 g gypsum powder was mixed with 94 mm$^3$ distilled water (Zolal, Tehran). In group B, 300 g gypsum powder was mixed with 94 mm$^3$ of 0.5% sodium hypochlorite solution (Shimin Inc., Tehran, Iran) (diluted with distilled water to 0.5%). In group C, 300 g gypsum powder was mixed with 90 mm$^3$ distilled water. Room temperature was kept at 25°C at all times and the environment humidity was 40% measured by the moisture meter (Moisture Meter, Delmhorst Instrument Co., Victoria, Australia). Setting time, setting expansion and compressive strength tests were separately carried out for all specimens. The ratio of water to gypsum powder was suggested to be 28-30cc water per 100g gypsum powder (24). This amount was tripled in our study considering the capacity of testing devices for physical characteristics. Dental stone mixing and tests were all done according to ADA specification No. 25 (25).

**Gypsum mixture preparation:**
Before mixing the gypsum powder with the respective liquid, the box containing gypsum powder was shaken well to homogenize the constituents. The powder was then mixed with the respective liquid at 25°C and a paste with desirable consistency was prepared. For this purpose, first specific amount of liquid was poured into the rubber bowl (with approximate diameter of 130mm at the opening, clean and scratch-free). The desired amount of powder was then gradually added during 10s; 20s time was allowed for wetting of powder particles. The mixture was then mixed with a spatula(21 mm width and 130 mm length) using circular motion with approximate speed of 120 rpm for one minute to obtain a paste with favorable consistency.

**Setting time test:**
Metal mould of Vicat apparatus (Vicat apparatus, Humblot manufacturing company, Chicago, IL, USA) with 50mm height and 35 mm internal diameter was completely filled with the mixture and the surface was smoothed with a spatula. One to 2 min prior to the expected time of setting, the valve screw was loosened to allow the needle tip of the apparatus (with 3mm diameter and 300g weight)penetrate into the stone paste. This was repeated every 30s and each time the mould was slightly repositioned to allow the needle penetrate into a new point. The needle was cleaned each time, its tip was placed in contact with the paste, the valve screw was tightened and the degree indicated by the stylus was read. The valve screw was then loosened rapidly in order for the needle to penetrate into the gypsum. The degree was then read again. This was repeated until the needle could not penetrate all the way to the bottom of the specimen. This position was considered as the termination of setting (23). Setting time of gypsum was calculated from the initiation of mixing to this point.

**Setting expansion test:**
First, a V-shaped stainless steel mould measuring 140x30x30 mm and thickness of 4mm was designed and fabricated. A brass cubic mold with 30mm dimensions and 200g weight was also used. This piece was mobile and could move in the V-shaped mould due to stone expansion.

Micrometer with 0.01 mm readability (Dial caliper, Mitutoyo, USA) was placed over the expansion-meter in a way that the V-shaped mould had 100 mm distance from the mobile piece (measured by caliper). The bottom of the V-shaped mould was covered with a rubber dam (SDI, Victoria, Australia). Then 150g of gypsum powder was mixed with the respective liquid as described earlier and poured into the V-shaped mould over the rubber dam using a spatula. The surface of paste was smoothed and covered with the rest of the rubber dam. The entire complex was placed into a plastic bag to prevent vaporization of liquid. One minute prior to
gypsum setting, the amount of expansion was read. Length of specimens was once again measured at 120 min. the test was repeated twice and the mean of obtained values was reported in hundredth of mm.

**Compressive strength testing:**
A two-piece mould was fabricated of a brass wire that included 5 adjacent cylinders with 20±0.2 mm diameter and 40±0.4 mm height according to the ADA standard dimensions. A total of 150g of gypsum was mixed with the desired amount of liquid as described earlier. The moulds were placed over a glass slab, filled with the gypsum paste and gently vibrated for 30s on a vibrator (Pars Dental, Tehran, Iran) to eliminate any possible void. Before the elimination of gypsum surface shine, another glass slab was placed on top of the moulds. Forty-five minutes after mixing, specimens were removed from the mould and placed into the plastic containers designed for alginate storage for 15min to prevent vaporization of moisture (at 23°C temperature and 95% humidity). After an hour, the samples were transferred to compressive strength testing machine (Walter+Baiag Testing Machine, Switzerland) to determine their wet strength. The machine had 0.01 kN readability with a crosshead speed of 8.5 kN/min. The obtained values at failure of each specimen were recorded.

Data were entered SPSS version 13 software. Considering the normal distribution of data (Kolmogorov-Smirnov and histogram with normal distribution curve), ANOVA was used to compare mean differences among the 3 groups \( (p<0.05) \). For pairwise comparison of groups, Tukey’s test was applied. \( p<0.05 \) was considered statistically significant.

**Results:**
Setting time (s), setting expansion (%) and compressive strength (MPa) of samples are demonstrated in Tables 1, 2 and 3, respectively.

<table>
<thead>
<tr>
<th>Group</th>
<th>Setting time (s)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>955 932 910 925</td>
<td>924</td>
<td>21.78</td>
</tr>
<tr>
<td>Group B</td>
<td>390 419 405 423</td>
<td>409.4</td>
<td>12.97</td>
</tr>
<tr>
<td>Group C</td>
<td>733 709 745 700</td>
<td>737.2</td>
<td>38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Setting expansion (%)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>0.32 0.31 0.32 0.32</td>
<td>0.32</td>
<td>0.005</td>
</tr>
<tr>
<td>Group B</td>
<td>0.33 0.33 0.32 0.32</td>
<td>0.32</td>
<td>0.005</td>
</tr>
<tr>
<td>Group C</td>
<td>0.30 0.28 0.29 0.30</td>
<td>0.29</td>
<td>0.008</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Compressive strength (MPa)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>12.72 16.36 14.54 14.54 15.15</td>
<td>14.662</td>
<td>1.31</td>
</tr>
<tr>
<td>Group B</td>
<td>18.78 20.97 16.97 18.78 18.48 18.792</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>Group C</td>
<td>18.18 16.36 15.75 13.94 18.45 16.536</td>
<td>1.85</td>
<td></td>
</tr>
</tbody>
</table>

The mean values of the abovementioned variables are shown in Diagrams 1, 2 and 3, respectively.
Setting time test:
The mean setting time was 924s in group A, 409.4s in group B and 737.2s in group C. ANOVA found significant differences in this respect among the 3 groups ($p<0.05$). Tukey’s test was used for pairwise comparison of groups and showed that setting time in group A was significantly longer than in groups B and C ($p<0.05$). Also, setting time of group C was longer than that of group B.

Setting expansion test:
The mean setting expansion was 0.316% in group A, 0.324% in group B and 0.292% in group C. According to ANOVA, the difference
in this respect among the 3 groups was statistically significant ($p<0.05$). Pairwise comparison of groups with Tukey’s test revealed no significant difference in this regard between groups A and B ($p>0.05$). But the setting expansions in groups A and B were greater than that of group C ($p<0.05$).

**Compressive strength test:**
The mean compressive strength was 14.662 MPa in group A, 18.727 MPa in group B and 16.536 MPa in group C. The difference in this respect among the 3 groups was statistically significant (ANOVA) ($p<0.05$). Pair wise comparison of groups with Tukey’s test showed that the mean compressive strength in group B was greater than in groups A and C ($p<0.05$).

**Discussion:**
Based on the obtained results, addition of sodium hypochlorite to type 3 dental stone had no adverse effect on the understudy physical properties of dental stone casts. Results showed that addition of sodium hypochlorite to distilled water increased the compressive strength of the produced stone models; which is a positive effect. This finding may be explained by the fact that by addition of sodium hypochlorite less amount of water is available to react with calcium sulfate hemihydrate in gypsum powder in order to convert it to calcium sulfate dihydrate. Thus, as reported in the literature, reducing the water/powder ratio in gypsum paste increases the compressive strength of the produced stone model (23, 24). Reduction in the amount of water also facilitates the conversion of calcium sulfate hemihydrate to calcium sulfate dihydrate. Thus, the setting time is decreased. Another explanation for the higher compressive strength and shorter setting time would be that sodium hypochlorite serves as the catalyst of the reaction and may exert its effect by increasing the solubility of calcium sulfate hemihydrate.

Small number of studies have evaluated the effect of addition of disinfectants to the water mixed with gypsum powder. Donovan and Chee in 1989 (26) studied type 4 modified dental stone called Steri-Die that contained Chloramine T solution incorporated into the gypsum powder. They reported that the setting time of stone models made of this composition significantly decreased compared to conventional dental stones. This finding is in accord with our obtained results. Their study also showed that setting expansion of models produced by mixing sterile die and water was twice the rate in models produced by mixing type 4 dental stone and water. This finding is in contrast to our obtained results. In 1998, Breault et al. (27) in a similar study stated that addition of 0.5% sodium hypochlorite to gypsum powder decreased the setting time and similar to our study, they found no significant difference in setting expansion between the 2 groups. Stern et al. in 1991 (17) evaluated the effect of disinfectants such as sodium hypochlorite, iodophor, phenol and glutaraldehyde on physical properties of stone casts and reported an increase in compressive strength of these casts compared to conventional casts. Surface properties of stone casts produced by mixing type 3 and 4 dental stone, gum Arabic and calcium hydroxide were evaluated by Abdelaziz et al. (28) in 2002 and it was revealed that the compressive strength of these casts was higher than that of conventional casts made of type 3 and 4 dental stone; which is in agreement with our findings. Twomey et al. (23) in 2003 suggested 0.5% calcium hypochlorite as a suitable disinfectant for incorporation into gypsum powder and reported that higher percentages of this material will decrease the strength of dental stone models. The difference between the mentioned study and ours may be attributed to the type and different percentages of the materials used. Considering the obtained results, use of sodium hypochlorite significantly reduced the setting time to an extent.
greater than did the lower volume of water; which is especially important in dental laboratories where time is an issue. By decreasing the amount of water, the setting expansion is decreased and in our study the setting expansion was higher in groups A and B. It should be noted that the preparation steps, type of dental stone and particularly method of mixing (mechanical versus manual) can affect and control the setting expansion. Although the difference between groups A and B was not significant, expansion in group B was greater than in group A. Considering the shrinkage of cast alloys, this expansion is overall favorable for compensation of metal shrinkage. As mentioned earlier, the mean compressive strength was higher in cases where sodium hypochlorite was used and this is a positive point for laboratory procedures particularly in Flasking and Processing of acrylic resin denture base materials.

**Conclusion:**

Addition of 0.5% sodium hypochlorite to distilled water for disinfection of dental stone casts decreased the setting time, increased the compressive strength and had no significant effect on setting expansion of stone models. Higher amount of distilled water increased the setting time and setting expansion but had no impact on compressive strength of samples.

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**Conflict of Interest:** “None Declared”

**References:**